# TEMPERATURES, PRESSURES, AND DENSITIES OF THE ATMOSPHERE AT VARIOUS LEVELS IN THE REGION OF NORTHEASTERN FRANCE.

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It is very desirable that summaries be made of, and generalizations drawn from, aerological data whenever they are sufficiently abundant, homogeneous and reliable to justify such treatment. The data used in the present study, because obtained at places of nearly the same latitude and of similar climates, meet these conditions as well as, if not better than, any other available; at least, with reference to the particular points discussed.

Table I, graphically represented by figures 1, 2, and 3, gives the seasonal (summer: June, July, August, and September; and winter: December, January, February, and March) and weather (cyclonic, anticyclonic, and neutral) vertical distribution of temperature in the atmosphere, in the region of northeastern France, from the surface up to 20 kilometers above sea level, as determined by 416 sounding balloon flights made from Trappes, Uccle, Strassburg and Munich. When two flights were made from the same place on the same day only one was used. With this exception, all flights attaining an altitude of 7 kilometers or more made at these stations from 1900 to 1912, inclusive (excepting December, 1912), and all now (1918) available, were used.

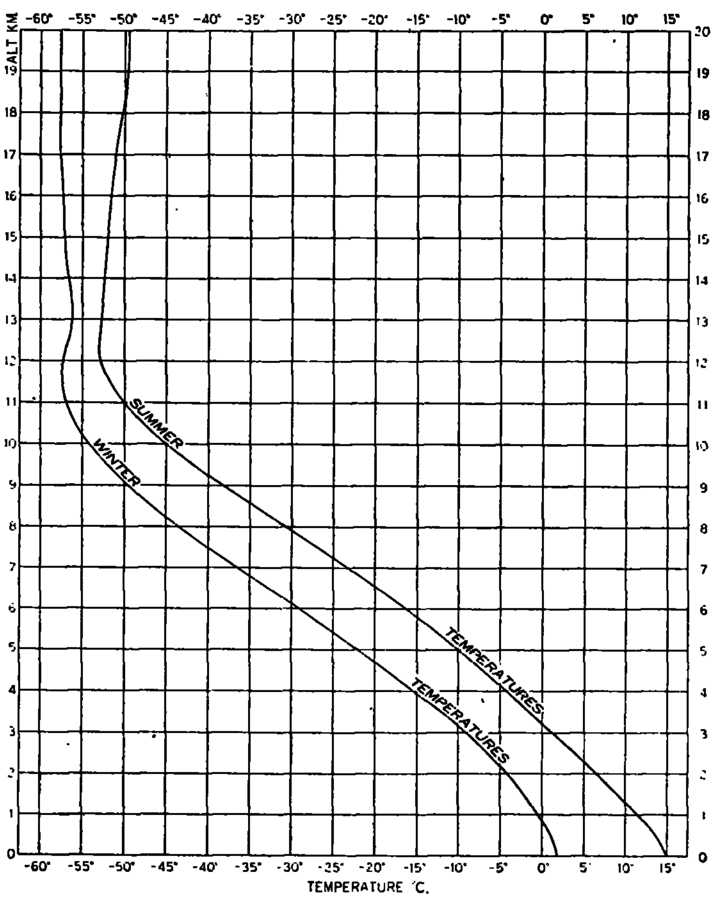

FIG. 1.—Average summer and winter temperatures in northeastern France.

Figure 1 shows the average summer and the average winter temperatures given by 231 and 185 flights, respectively. These curves beyond 8 kilometers do not give exactly, though very nearly, the averages of the observed temperatures, as they do up to that level, but show the averages of the observed temperature gradients. That is, from the level at which the number of observations began to decrease, both curves of average temperature were extended by means of their average gradients. This procedure is believed to give temperatures nearer the true average than would the averages, step by step, of the decreasing numbers of actually observed temperatures.

By averaging the data of a large number of flights, the obvious advantage is gained of correspondingly reducing the effects of accidental errors and fortuitous irregularities. At the same time, however, one serious error is introduced, namely, the gradual change of the temperature gradient between the levels of 8 or 9 and, roughly, 12 kilometers. In nearly all individual cases the change of this gradient is much more abrupt, but as it ranges over 2 or 3 kilometers and, say, 15°C. it follows that the average gives a fictitiously gradual change of the gradient.

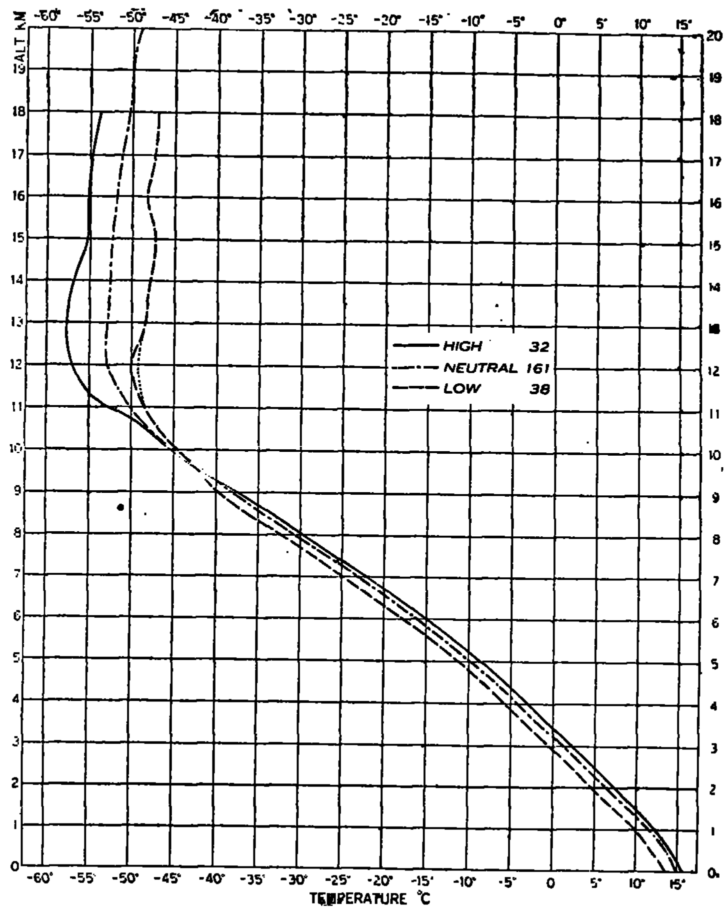

FIG. 2.—Average summer temperatures in the region of northeastern France. "HIGH" barometer 5 mm. or more above normal. "LOW" barometer 5 mm. or more below normal. "NEUTRAL" all between "HIGH" and "LOW". Number of flights averaged: HIGH, 54; NEUTRAL, 161; and LOW, 38.

Figures 2 and 3 give the results obtained on grouping the summer and winter flights, respectively, according to the surface pressure. The full line in each figure shows the average vertical temperature distribution when the barometer reads 5 millimeters or more greater than its normal value for the places and season in question.

Similarly, the broken line corresponds to pressures 5 millimeters or more below the normal, and the dot and dash line to pressures between these extremes. According to this division there were, for the summer, 32 highs, 38 lows, and 161 neutrals; and for the winter, 54 highs, 59 lows, and 72 neutrals.

It will be noticed that, on the average, the whole of the troposphere, except below about 1 kilometer—and that during winter—is warmest during the prevalence of anticyclonic conditions and coldest in cyclones. Below 1 kilometer the temperature relations are reversed during the winter, owing to the prevalence then, on clear nights, of radiational, or surface, temperature inversions. It will also be noticed that in the stratosphere the above-mentioned temperature relations are reversed—the higher temperatures pertaining to cyclones and the lower to anticyclones.

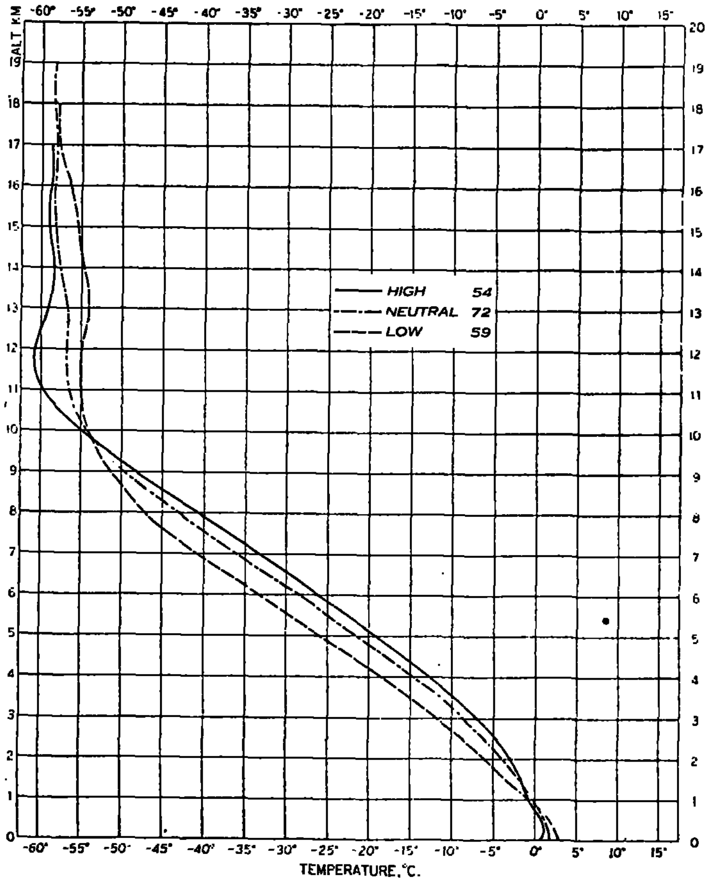


FIG. 3.—Average winter temperatures in the region of northeastern France. "HIGH" barometer 5 mm. or more above normal. "LOW" barometer 5 mm. or more below normal. "NEUTRAL" all between "HIGH" and "LOW". Number of flights averaged: HIGH, 54; NEUTRAL, 72; and LOW, 59.

It would be very instructive, of course, to average the temperature data according to the section of the cyclone or anticyclone in which it was obtained, but it seemed doubtful whether the flights were sufficiently numerous to justify such minute subdivision, and it, therefore, was not undertaken.

Figure 4, graphically representing the corresponding portions of Table II, gives the average summer and winter pressures, at all elevations from sea level up to 40 kilometers. These are not directly observed values, but, what comes to the same thing, values computed from the average temperatures and corrected for humidity, and the latitude and altitude effects on gravity. The temperatures used were those of Table I up to 11 and 12 kilometers for winter and summer, respectively. At and beyond 12 and 13 kilometers the winter and summer temperatures were assumed to be −57° C. and −52° C., respectively.

The summer and winter vapor pressures given in Table II and shown on the in-set to figure 4 were based, the first on the records of 193, and the second on the records of 141 individual flights.

Figure 5, representing the corresponding portions of Table II, gives the average summer and winter densities, the absissas being grams per cubic meter, or densities multiplied by $10^6$. These curves and the values they represent, which are corrected for humidity, are based on the pressures and temperatures corresponding to figure 4.

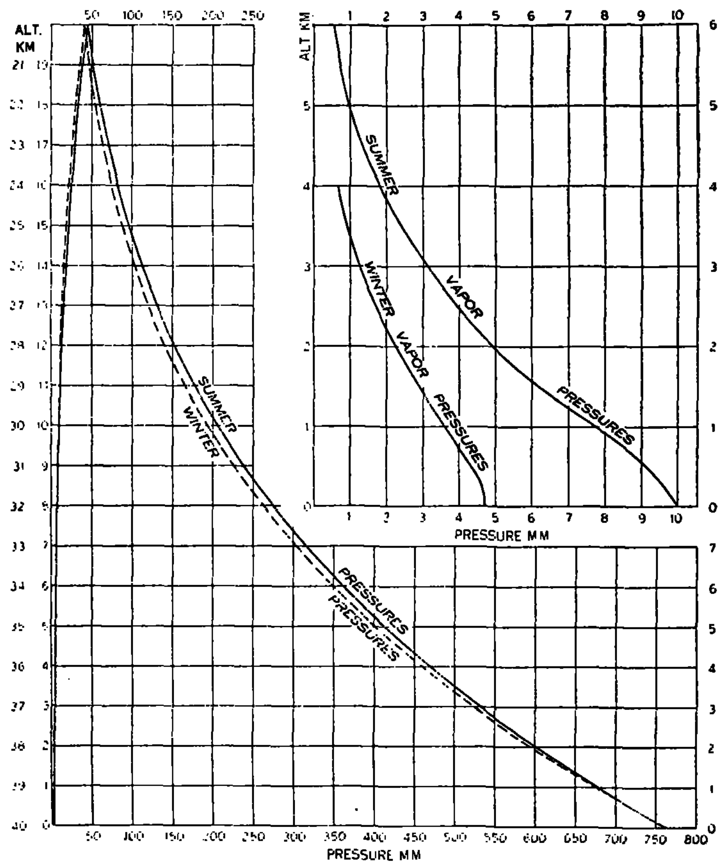


FIG. 4.—Average atmospheric and vapor pressures in the region of northeastern France. Number of cases averaged: Winter, 185; summer, 231.

Although in computing Table II the full hypsometric equation was used, thus correcting for humidity and the gravity effects of latitude and elevation, no account was taken of the probable differences in the percentage composition of the atmosphere at the higher levels. This was for two reasons: (a) because the amount of such change is uncertain, and (b) because, at most, it could not affect the values given, already small, by more than 1 per cent.

TABLE I.—*Average temperatures, centigrade (from average temperature gradients) from 416 sounding-balloon flights at Trappes, Uccle, Strassburg, and Munich, 1900–1912.*

[Temperature, T; number of cases, N.]

| Altitude in kilometers above sea level. | Summer. | | | | | | | | Winter. | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | High. | | Neutral. | | Low. | | Mean. | | High. | | Neutral. | | Low. | | Mean. | |
| | T. | N. | T. | N. | T. | N. | T. | N. | T. | N. | T. | N. | T. | N. | T. | N. |
| 0.0 | 15.54 | 29 | 14.82 | 121 | 13.58 | 28 | 14.76 | 178 | 0.67 | 43 | 1.61 | 55 | 2.85 | 49 | 1.72 | 147 |
| 0.5 | 13.98 | 29 | 13.90 | 121 | 11.93 | 28 | 13.60 | 178 | 0.87 | 43 | 1.01 | 55 | 1.77 | 49 | 1.23 | 147 |
| 1.0 | 12.39 | 32 | 12.12 | 161 | 9.98 | 38 | 11.81 | 231 | − 0.63 | 54 | − 0.49 | 72 | − 0.80 | 59 | − 0.63 | 185 |
| 1.5 | 9.57 | 32 | 9.34 | 161 | 7.23 | 38 | 9.03 | 231 | − 1.56 | 54 | − 1.77 | 72 | − 3.50 | 59 | − 2.26 | 185 |
| 2.0 | 7.09 | 32 | 6.54 | 161 | 4.55 | 38 | 6.29 | 231 | − 2.75 | 54 | − 3.76 | 72 | − 5.92 | 59 | − 4.16 | 185 |
| 2.5 | 4.37 | 32 | 3.84 | 161 | 2.12 | 38 | 3.63 | 231 | − 4.60 | 54 | − 6.10 | 72 | − 8.66 | 59 | − 6.48 | 185 |
| 3.0 | 2.00 | 32 | 1.19 | 161 | − 0.49 | 38 | 1.02 | 231 | − 6.92 | 54 | − 8.65 | 72 | −11.75 | 59 | − 9.14 | 185 |
| 4.0 | − 3.16 | 32 | − 4.16 | 161 | − 5.74 | 38 | − 4.28 | 231 | −12.60 | 54 | −14.69 | 72 | −18.44 | 59 | −15.30 | 185 |
| 5.0 | − 8.74 | 32 | − 9.83 | 161 | −11.33 | 38 | − 9.93 | 231 | −19.22 | 54 | −21.49 | 72 | −25.91 | 59 | −22.24 | 185 |
| 6.0 | −15.11 | 32 | −16.15 | 161 | −17.86 | 38 | −16.29 | 231 | −26.18 | 54 | −28.40 | 73 | −33.37 | 59 | −29.33 | 185 |
| 7.0 | −22.18 | 32 | −23.12 | 161 | −24.80 | 38 | −23.26 | 231 | −33.27 | 54 | −35.80 | 71 | −40.83 | 59 | −36.63 | 184 |
| 8.0 | −29.82 | 32 | −30.59 | 161 | −32.34 | 38 | −30.77 | 231 | −40.83 | 53 | −43.10 | 70 | −47.13 | 59 | −43.63 | 182 |
| 9.0 | −37.62 | 31 | −38.08 | 159 | −39.77 | 37 | −38.27 | 227 | −48.05 | 50 | −49.70 | 67 | −51.33 | 57 | −49.63 | 174 |
| 10.0 | −45.32 | 31 | −44.88 | 155 | −44.57 | 36 | −44.87 | 222 | −54.85 | 48 | −54.30 | 64 | −54.23 | 53 | −54.33 | 165 |
| 11.0 | −52.62 | 31 | −50.08 | 149 | −48.37 | 34 | −50.07 | 214 | −59.65 | 44 | −56.50 | 56 | −55.03 | 47 | −56.83 | 147 |
| 12.0 | −57.02 | 30 | −52.68 | 133 | −49.97 | 30 | −52.87 | 193 | −60.75 | 38 | −56.80 | 45 | −54.93 | 37 | −57.23 | 120 |
| 13.0 | −57.62 | 27 | −52.78 | 117 | −48.27 | 27 | −52.77 | 171 | −59.05 | 34 | −56.70 | 34 | −54.23 | 30 | −56.33 | 98 |
| 14.0 | −56.82 | 22 | −52.48 | 104 | −47.87 | 21 | −52.37 | 147 | −58.35 | 26 | −57.70 | 22 | −54.73 | 24 | −56.53 | 72 |
| 15.0 | −55.32 | 18 | −52.38 | 81 | −47.37 | 17 | −51.97 | 116 | −58.85 | 17 | −58.20 | 16 | −55.43 | 16 | −57.13 | 49 |
| 16.0 | −55.32 | 13 | −51.68 | 61 | −48.17 | 8 | −51.57 | 82 | −58.55 | 11 | −58.30 | 12 | −56.43 | 10 | −57.33 | 33 |
| 17.0 | −54.82 | 9 | −51.18 | 36 | −47.37 | 4 | −51.07 | 49 | −58.65 | 5 | −58.00 | 9 | −57.63 | 7 | −57.63 | 21 |
| 18.0 | −53.82 | 8 | −50.38 | 22 | −46.97 | 3 | −50.17 | 33 | | | −58.30 | 6 | −57.83 | 5 | −57.63 | 13 |
| 19.0 | | | −49.88 | 17 | | | −49.57 | 21 | | | −58.20 | 5 | | | −57.63 | 8 |
| 20.0 | | | −48.98 | 15 | | | −48.97 | 18 | | | | | | | −57.63 | 5 |

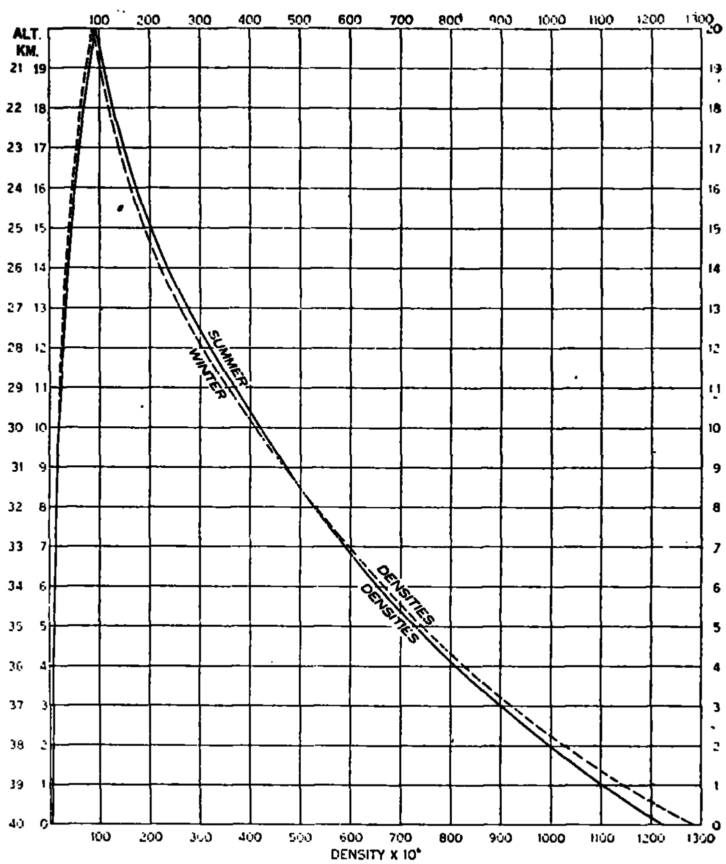


FIG. 5.—Average atmospheric densities in the region of northeastern France. Number of cases averaged: Winter, 185; summer, 231.

TABLE II.—*Average grams per cubic meter ($\rho \times 10^6$, $\rho$=density) and millimeters pressure (total, and water vapor) from 231 summer and 185 winter sounding-balloon flights at Trappes, Uccle, Strassburg, and Munich, 1900–1912.*

| Altitude in kilometers above sea level. | Summer. | | | Winter. | | |
|---|---|---|---|---|---|---|
| | Total pressure. | Vapor pressure. | Grams per cubic meter. | Total pressure. | Vapor pressure. | Grams per cubic meter. |
| 0.0 | [1] 762.55 | 10.46 | 1,224.42 | [1] 763.35 | 4.69 | 1,287.58 |
| 0.5 | 718.75 | 9.17 | 1,159.17 | 717.42 | 4.35 | 1,212.31 |
| 1.0 | 677.24 | 7.81 | 1,099.61 | 674.11 | 3.56 | 1,147.23 |
| 1.5 | 637.81 | 6.21 | 1,046.50 | 633.12 | 2.93 | 1,084.23 |
| 2.0 | 600.31 | 4.97 | 995.19 | 594.37 | 2.27 | 1,025.03 |
| 2.5 | 564.67 | 3.97 | 945.56 | 557.71 | 1.71 | 970.08 |
| 3.0 | 530.82 | 3.12 | 897.73 | 522.99 | 1.30 | 919.87 |
| 4.0 | 468.23 | 1.87 | 808.07 | 458.91 | 0.72 | 826.62 |
| 5.0 | 411.93 | 1.06 | 726.57 | 401.32 | | 743.33 |
| 6.0 | 361.32 | 0.57 | 653.35 | 349.62 | | 666.41 |
| 7.0 | 315.84 | | 587.39 | 303.34 | | 596.05 |
| 8.0 | 274.98 | | 527.26 | 261.94 | | 530.41 |
| 9.0 | 238.39 | | 471.70 | 225.37 | | 468.61 |
| 10.0 | 205.77 | | 418.94 | 193.19 | | 410.34 |
| 11.0 | 176.95 | | 368.66 | 165.19 | | 355.20 |
| 12.0 | 151.80 | | 319.03 | 141.11 | | 303.43 |
| 13.0 | 130.14 | | 273.51 | 120.55 | | 259.22 |
| 14.0 | 111.58 | | 234.50 | 102.99 | | 221.46 |
| 15.0 | 95.67 | | 201.06 | 87.99 | | 189.20 |
| 16.0 | 82.03 | | 172.40 | 75.18 | | 161.66 |
| 17.0 | 70.34 | | 147.83 | 64.24 | | 138.13 |
| 18.0 | 60.32 | | 126.77 | 54.89 | | 118.03 |
| 19.0 | 51.73 | | 108.72 | 46.91 | | 100.87 |
| 20.0 | 44.37 | | 93.25 | 40.09 | | 86.20 |
| 21.0 | 38.05 | | 79.97 | 34.26 | | 73.67 |
| 22.0 | 32.64 | | 68.60 | 29.28 | | 62.96 |
| 23.0 | 27.99 | | 58.82 | 25.02 | | 53.80 |
| 24.0 | 24.01 | | 50.46 | 21.39 | | 45.99 |
| 25.0 | 20.60 | | 43.29 | 18.28 | | 39.31 |
| 26.0 | 17.67 | | 37.14 | 15.63 | | 33.61 |
| 27.0 | 15.16 | | 31.86 | 13.36 | | 28.73 |
| 28.0 | 13.01 | | 27.34 | 11.42 | | 24.56 |
| 29.0 | 11.16 | | 23.45 | 9.77 | | 21.01 |
| 30.0 | 9.58 | | 20.13 | 8.35 | | 17.95 |
| 31.0 | 8.22 | | 17.28 | 7.14 | | 15.35 |
| 32.0 | 7.05 | | 14.82 | 6.10 | | 13.12 |
| 33.0 | 6.05 | | 12.72 | 5.22 | | 11.24 |
| 34.0 | 5.19 | | 10.91 | 4.46 | | 9.59 |
| 35.0 | 4.46 | | 9.37 | 3.82 | | 8.21 |
| 36.0 | 3.83 | | 8.05 | 3.27 | | 7.03 |
| 37.0 | 3.28 | | 6.89 | 2.79 | | 6.00 |
| 38.0 | 2.82 | | 5.93 | 2.39 | | 5.14 |
| 39.0 | 2.42 | | 5.09 | 2.04 | | 4.39 |
| 40.0 | 2.08 | | 4.37 | 1.75 | | 3.76 |

[1] Normal for the season.